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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : A42B 3/06

A1

(11) International Publication Number: WO 90/14025

(43) International Publication Date: 29 November 1990 (29.11.90)

(21) International Application Number: PCT/AU90/00211

(22) International Filing Date: 22 May 1990 (22.05.90)

(30) Priority data:
PJ 4342 23 May 1989 (23.05.89) AU

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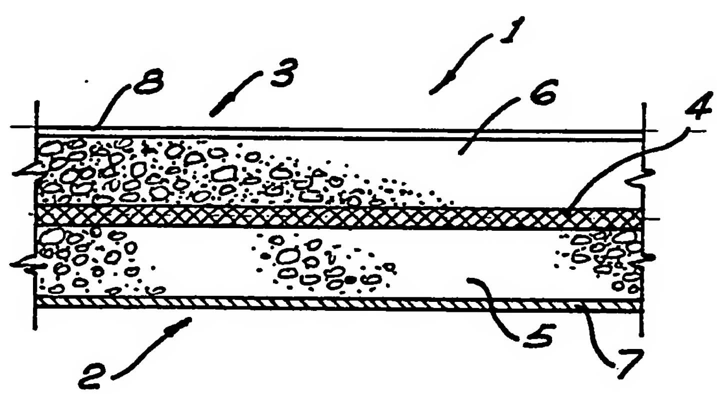
(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE*, DE (European patent)*, DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.

(54) Title: CRASH HELMET



(57) Abstract

A crash helmet of the kind worn by cyclists or others is formed from a laminate comprising a penetration resistant membrane (4), a deformation damping layer (6) and optionally a cushioning layer (5). The deformation damping layer is preferably a polystyrene foam having a density in excess of 57 g/l, more preferably in excess of 85 g/l.

* See back of page

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Title: "CRASH HELMET"

Technical Field of the Invention

This invention relates to a crash helmet of the kind worn by cyclists, riders, parachutists, industrial workers and others for the protection of a wearer from accidental head injury.

Background art

A crash helmet is desirably capable of distributing impact loads over a large area. Studies on the fracture mechanics of cranial bone show that if a force is applied over a small area of the skull, a localized depressed fracture of the cranial bone can occur at considerably lower loads than if the force were distributed over a greater area of skull.

Experimentation on cadavers has indicated that depressed fracture can occur if the struck area of skull is less than about 13 cm^2 (SAE, 1980). The force

required to produce depressed fracture was shown to vary considerably but the threshold for fracture appeared to be about 2 kilonewton.

Desirably also crash helmets provide resistance to penetration by sharp objects and are of light weight to avoid causing spinal injuries.

Conventional crash helmets comprise two main parts, an outer shell and an inner liner. The outer shell is usually a polycarbonate, ABS, or fibreglass reinforced resin of approximately 3 mm - 5 mm shell thickness. The outer layer functions to provide penetration resistance, styling and a smooth, low wind resistance exterior as well as giving mechanical support to an inner liner. The inner liner is a separate polystyrene foam moulding of from 15 mm to 40 mm thickness which is a snug fit into the shell. The liner is usually a 40 - 60 grade polystyrene foam which is selected so that the polystyrene foam will collapse under load, thus absorbing impact energy and providing impact resistance. Grade number is a measure of polystyrene foam density, the grade number increasing as the density increases. Grade number corresponds to the density expressed in grams/litre.

In addition, conventional helmets may be provided with comfort padding inside the liner and with retention straps or the like generally secured by rivets to the outer shell.

While safety helmets of the above kind are generally satisfactory, the weight of the helmet often detracts from comfort and is believed to increase the potential for spinal injury. Weight is considered especially critical when helmets are worn by children. In some cases, helmets are given to failure at the anchor points of the restraining strap.

Tests have shown that the outer shell of a conventional helmet deforms elastically during impact involving a concentrated load. The shell causes the load to be distributed over a greater area of surface than the cross section of the struck object.

However, in some circumstances, for example when worn in a collision, the outer shell may resiliently deform towards the skull as the skull compresses the load absorbing polystyrene layer and as the brain is driven towards the crown of the skull. It has now been discovered that, at about the moment of maximum compression, energy of deformation stored in the shell may be released as the outer shell resiliently snaps back towards its undeformed state with the risk that the energy released may contribute to brain injury.

Helmets marketed for cyclists have been mo ided entirely from polystyrene foam and are thus of lighter weight than those having a hard outer shell. However, foam helmets have poor penetration resistance. Furthermore, they display poor impact resistance to

concentrated loads, lacking capacity to distribute load laterally through the foam when the impact load is concentrated in an area of less than about 20 cm^2. In comparison with conventional hard shell helmets, polystyrene foam helmets may be capable of providing equal or superior impact resistance for non-concentrated loads but have poor penetration resistance and a low capacity for distributing concentrated impact loads.

In general in terms of penetration and impact resistance the best performing conventional hard outer shell helmets are those having the thickest outer shell which are the heaviest and have the greatest potential for spinal injury. The best performing of the polystyrene moulded cyclists helmets are those which have the thickest foam and are the most bulky. Bulkiness is disadvantageous because it may introduce leverage or rotation in the event of an accident. These helmets have poor penetration resistance and fail to distribute concentrated loads.

An object of the present invention is to provide a crash helmet which avoids or at least ameliorates some of the disadvantages of prior art discussed above.

A further object of preferred embodiments is to provide a crash helmet of a construction which provides a desirable combination of penetration resistance, and lightness of weight, while reducing the force transmitted from a concentrated or a non-concentrated

impact.

Disclosure of the Invention

According to one aspect, the present invention consists in a crash helmet formed substantially from a laminate, said laminate comprising penetration resistant membrane and a deformation damping layer.

In preferred embodiments of the invention, the penetration of the laminate resistant membrane is a fibre reinforced resin for example a fibreglass reinforced epoxy resin and the damping layer is of a dense polystyrene foam having a density grade of greater than 57 and more preferably of greater than 85.

For light-weight helmets such as used by cyclists, the helmet may be constructed from a laminate consisting only of the penetration resistant membrane and the damping layer and in that case the membrane is preferably the outer-most layer. In heavier duty helmets such as those intended for use by motor cyclists, a cushioning layer is preferably included in the laminate and in that case the damping layer is desirably exterior of the membrane and the cushioning layer is interior of the membrane.

Brief Description of Drawings

An embodiment of the present invention will now be described by way of example only with reference to the accompanying drawings wherein:

Figure 1 is a schematic diagram, not to scale,

showing a scrap cross-section through a portion of a first crash helmet according to the invention;

Figure 2 is a schematic diagram, not to scale, showing a scrap cross-section through a portion of a second embodiment of the invention;

Figure 3 is a graph showing impact acceleration versus time obtained from a drop test on a first control crash helmet;

Figure 4 is a graph similar to Figure 3 obtained for a test of a second control crash helmet; and

Figure 5 is a graph similar to that of figures 3 and 4 obtained from an embodiment of the invention.

Preferred embodiments of the Invention

The first embodiment to be described comprises a crash helmet shaped from a laminate 1 (shown in cross-section in Figure 1) having an interior side 2 with respect to the finished helmet and an exterior side 3 with respect to the finished helmet. The helmet includes a penetration resistant membrane 4, a cushioning layer 5 on the interior side of the membrane and a deformation damping layer 6 on the exterior side of the membrane.

The cushioning layer is a polystyrene foam of, for example, from 6 mm - 20 mm thickness and of 35 - 85 density grade, more preferably 6 mm - 15 mm thickness and from 35 - 60 density grade and is selected to absorb impact energy in a conventional manner.

Deformation damping layer 6 is preferably a high density polystyrene foam having a grade of greater than 57, preferably of greater than 70, and more preferably greater than 90 and having a nominal thickness of approximately from 6 mm to 20 mm.

In preferred embodiments, membrane 4 is a woven fibreglass cloth for example COLON 402 S Class 369 - 68.5 Standard Weave - 4 oz. impregnated with a plasticized epoxy resin (e.g. resin 2216 B/A available from the 3M company). The cloth is bonded to both the damping layer 6 and to cushioning layer 5 by means of the impregnation resin (not shown in the drawing).

The helmet may optionally be provided with comfort padding 7 on interior side 2. An outermost coating 8 of resin, or of cloth, or of a paint film or a light A.B.S. may optionally be provided on the exterior surface of the helmet to provide surface properties such as low wind resistance, durability or aesthetics. Attachment means (not illustrated) may be integral with the load distribution membrane, or may be secured to the membrane cloth e.g. by sewing or by resin bonding or may be mounted to the helmet by conventional means.

In comparison with a helmet constructed solely from polystyrene foam, a laminate according to the invention provides greatly improved penetration resistance. For example, when a 4 kilogram dart is dropped on a sample consisting of 2 mm x 25 mm thicknesses x 150 mm square

foam of 35 Kg/mm^3 of polystyrene using a helmet testing rig according to Australian Standard 2512.4 (Determination of Penetration Resistance - Part 3) the materials fail at a drop height of 500 mm penetration (applied impact energy 14.7 Joules). Material according to the invention utilizing 2 Colon 402S x 25 mm thicknesses of the same polystyrene sandwiching a fibreglass woven cloth bonded therebetween using epoxy resin 2216 B/A as hereinbefore described failed at a drop height of 800 mm (applied impact energy of 23.5 joules). This represents approximately. 60% increase in impact energy resistance.

Helmets according to the invention may be manufactured by moulding each of the polystyrene foam damping liner 6 and the polystyrene foam cushioning liner 5, the latter being designed as a press or neat fit into the damping layer. The interior surface of damping layer 6 is then coated with resin, the damping layer then being lined with the fibreglass membrane cloth and further coated with resin to complete membrane 4. If desired, retention straps and the like may be resin bonded to the membrane layer at this stage. The inner liner (cushioning layer 5) is then pushed into damping layer 6.

With reference to Figure 2 there is shown a light-weight laminate for use in a cyclist's helmet according to a second embodiment of the invention. The

laminate has an interior side 2 and exterior side 3 with respect to the finished helmet and has a penetration resistant membrane 4 of epoxy resin reinforced by a fibreglass cloth as previously described. A deformation damping layer 6 comprises a polystyrene foam having a density grade greater than 60 and preferably greater than 85 and has a thickness of from 10 mm - 30 mm, more preferably from 15 mm to 40 mm. The external resin layer may be pigmented to provide an alternative glossy coloured finish to the helmet and may be brushed or sprayed directly onto the foam layer which is moulded into a helmet shape before coating.

Foams of suitable density made of other polymers such as polyurethane or PVA may be substituted for polystyrene in less highly preferred embodiments.

The laminate of the invention provides the same or greater penetration resistance as prior art helmets at a substantially reduced weight and without loss of impact energy absorption at the required levels. The weight of preferred embodiments according to the invention may be as much as 25% less than that of conventional crash helmets. Furthermore, by virtue that the penetration resistant membrane is thinner and is damped against resilient deformation by being bonded on its inner or outer or preferably on both sides of the membrane, the membrane is less likely than prior art to store and release energy during resilient deformation and thus

cause brain damage during impact.

In addition, helmets according to the invention provide impact resistance over a wide range of load distributions including concentrated and distributed loads.

When a cushioning layer is employed the use of foams of differing densities in the construction spreads the impact absorption over time as well as area because the foams collapse at a different rate under impact thus attenuating the peak transmitted force.

Tests have shown that a helmet according to the invention which incorporates a conventional cushioning layer, 4 oz fibreglass penetration resistant membrane and a 10 mm outer layer substantially reduces the peak force exerted upon the user. This is achieved by the action of the components of the helmet leading to the user being subjected to a much reduced force over a longer period of time.

With reference to figures 3 to 6, there are shown the results of tests in which the acceleration transmitted through a helmet to an underlying headform are measured when an anvil of predetermined shape is dropped from a predetermined drop height.

The graphs show acceleration on the co-ordinate versus time on the abscissa.

Figure 3 shows the result of the test on a coventional helmet with hard outer shell and standard

pop in foam liner as a first control.

Figure 4 shows the result of the test on a conventional helmet liner without hard shell as a second control.

Figure 5 shows the results of the same test procedure performed on a helmet according to the invention comprising a 4 oz. fibreglass membrane epoxy resin bonded to a 10 mm damping layer of polystyrene foam (grade 70) as an outer layer.

It will be seen that whereas the conventional helmet of Figure 3 producers a first acceleration level peak on impact followed by a second and greater peak due to resilient deformation, and most of the impact is transmitted within a short time, in the case of the helmet according to the invention (Figure 5) the acceleration level on impact is considerably lower, being distributed over a much longer period.

Selection of high density polystyrene foam as the damping layer is preferred since it permits styling to take account of various safety factors such as wind resistance, lift, and mechanical effects which become important in collisions. Advantageously the damping layer may be easily abraded or broken away in comparison with penetration resistant prior art shells in the event of friction e.g. against a roadway, thus further reducing load on the wearer and absorbing impact energy under certain accident conditions.

In other embodiments of the invention, the outer layer may be made of other materials for example a vacuum formed PVC skin, a dressing fabric, a polyurethane foam, a skinned polyurethane or the like. The penetration resistant membrane may merely be a plasticized resin and need not be fibre reinforced although reinforcement is highly preferred. Other suitable penetration resistant membranes may utilize kevlar, carbon fibre or the like in place of fibreglass. The membrane may be a woven fabric or a non-woven batt or mat or fibres. In other embodiments of the invention laminates having more than three layers may be used.

For example a plurality of layers of foam of differing density may be employed and/or more than one penetration resistant membranes may be utilized.

As will be apparent to those skilled in the art from the teaching hereof, crash helmets according to the invention may be made in a variety of shapes and may be manufactured by means other than described above. For example, the fibreglass resin and matt may be applied to the cushioning layer which may then be combined with the damping layer or the resin may be cured prior to combining the cushioning and damping layers. Materials having properties similar to those herein described may be substituted for the various constituents of the preferred embodiment and all such variations are deemed to be within the scope of the invention herein disclosed.

CLAIMS:-

1. A crash helmet formed substantially from a laminate, said laminate comprising a penetration resistant membrane and a deformation damping layer.

2. A crash helmet according to Claim 1 wherein the deformation damping layer is a polystyrene foam having a density grade in excess of 57.

3. A crash helmet according to claim 1 or Claim 2 wherein the deformation damping layer is a polystyrene foam having a density grade in excess of 85.

4. A crash helmet according to any one of the preceding claims wherein the penetration resistant membrane comprises a fibre reinforced resin.

5. A crash helmet according to Claim 4 wherein the reinforcing fibre is selected from the group consisting of fibreglass, kevlar and carbon fibre.

6. A crash helmet according to any one of claims 2 or 3 wherein the resin is an epoxy resin.

7. A crash helmet according to any one of the preceding claims having a helmet interior side and a helmet exterior side and wherein the penetration resistant membrane is on the exterior side of the deformation damping layer.

8. A crash helmet according to any one of claims 1 to 7 further comprising a cushioning layer.

9. A crash helmet according to Claim 8 wherein the cushioning layer is a polystyrene foam having a grade in

the range of from 35 to 57.

10. A crash helmet according to Claims 8 or Claim 9 wherein the damping layer is on the exterior side of the penetration resistant membrane and the cushioning layer is on the interior side.

11. A crash helmet according to any one of the preceding claims wherein the deformation damping layer has a thickness in the range of from 6 mm to 40 mm.

12. A crash helmet according to any one of claims 8 to 11 wherein the cushioning layer has a thickness in the range of 6 mm to 20 mm.

13. A crash helmet according to any of the preceding claims including attachment means for releasably securing said helmet to a user.

15. A crash helmet according to Claim 1 for use by a cyclist and comprising a penetration resistant membrane of fibreglass cloth reinforced epoxy resin laminated with a deformation damping layer of polystyrene foam having a density grade of greater than 85, the damping layer having a thickness of from 15 mm - 40 mm.

16. A crash helmet according to any of the preceding claims substantially as herein described with reference to the accompanying drawings.

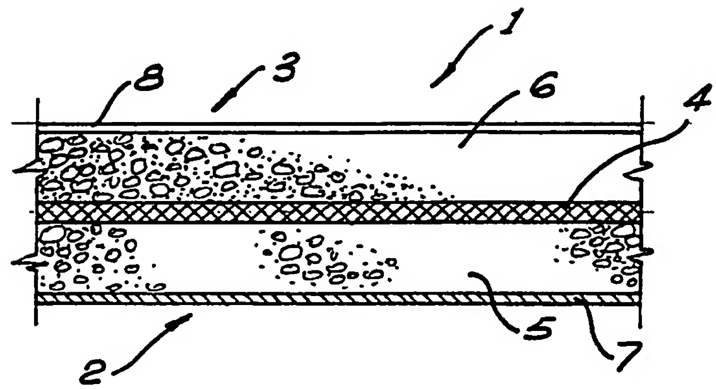

FIG. 1

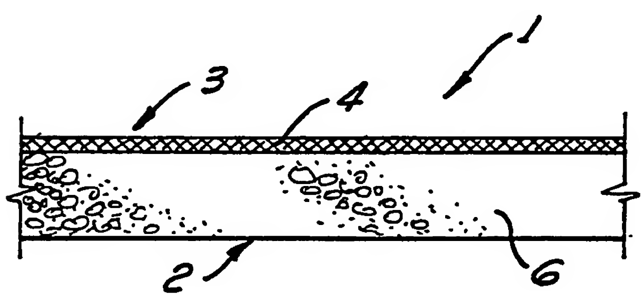

FIG. 2

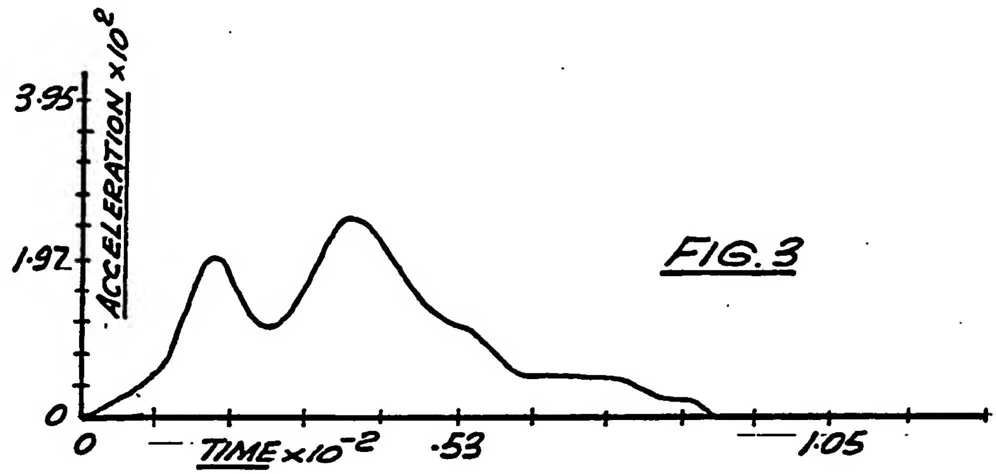

FIG. 3

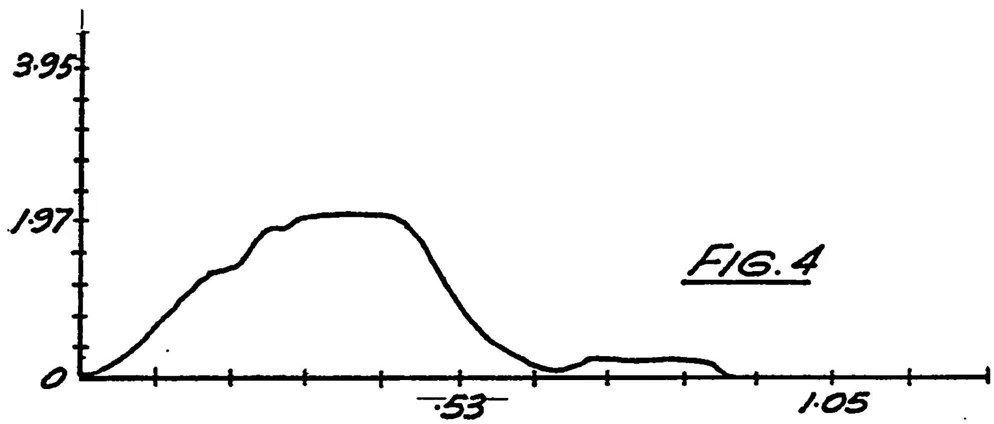

FIG. 4

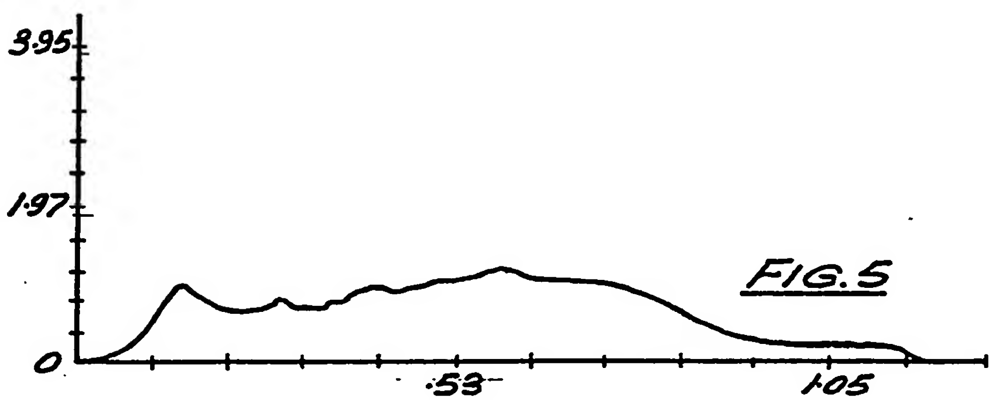

FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 90/00211

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.5 A42B 3/06

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
US Cl	2/412
IPC	A42B 3/02, 3/06

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	US,A, 3818508 (LAMMERS et al) 25 June 1974 (25.06.74)	
	col 2, lines 27-39	(1, 4, 5, 7, 10)
	col 3, lines 34-37	(8)
	col 2, line 3	(13)
X	US,A, 4101983 (DERA et al) 25 July 1978 (25.07.78)	
	col 2, lines 23 and 45	(1, 7)
	col 2, line 49	(11)
	col 2, line 35	(13)
	(continued)	

* Special categories of cited documents: 10

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
25 July 1990 (25.07.90)	3 August 1990
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	B.R. DASHWOOD

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	WO,A, 86/01380 (FIGGIE INTERNATIONAL INC.) 13 March 1986 (13.03.86)	
	page 9, 10 and page 4, lines 9-14	(1, 7)
	page 4, line 10	(4, 5)
	page 6, line 17	(8)
	page 6, lines 14-22	(10)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 90/00211

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
WO 8601380	CA 1245801 US 4627114	EP 190281	JP 62500037
US 3818508	CA 1018301	DE 2362325	GB 1420703
US 4101983	BE 855174 FR 2353240 NL 7706188	DE 2724984 GB 1553936	ES 238799 IT 1083406

END OF ANNEX

5,24JH/98/1